

1 What is claimed is:

- 1 1. A method for forming a waveguide structure, comprising:  
2 forming a light propagating channel in a lower cladding;  
3 filling the light propagating channel with a core material to form a core;  
4 forming an upper cladding over the core.
- 1 2. The method of claim 1 further comprising planarizing the core material and the  
2 lower cladding prior to forming an upper cladding over the core.
- 1 3. The method of claim 2 wherein planarizing the core material and the lower  
2 cladding comprises etching or chemical mechanical polishing.
- 1 4. The method of claim 1 wherein the lower cladding is deposited on a substrate.
- 1 5. The method of claim 1 wherein the lower cladding comprises a material having a  
2 refractive index lower than the refractive index of the core material.
- 1 6. The method of claim 1 wherein the lower cladding is a substrate.
- 1 7. The method of claim 1 wherein forming the light propagating channel in the lower  
2 cladding comprises patterning and etching a light propagating channel in the lower  
3 cladding.
- 1 8. The method of claim 6 wherein forming the light propagating channel in the lower  
2 cladding comprises patterning and etching a light propagating channel in the  
3 substrate.
- 1 9. The method of claim 4 wherein the core material comprises PSG, GeO<sub>2</sub>, SiON,  
2 Si<sub>3</sub>N<sub>4</sub>, and silicon.
- 1 10. The method of claim 9 wherein the lower cladding comprises a material selected  
2 from the group of USG and undoped silica.

- 1 11. The method of claim 10 wherein the upper cladding comprises BPSG.
- 1 12. The method of claim 9 wherein forming the upper cladding comprises depositing a  
2 film using chemical vapor deposition or physical vapor deposition techniques.
- 1 13. The method of claim 1 wherein forming an upper cladding comprises bonding a  
2 pre-formed upper cladding to the lower cladding and the core.
- 1 14. The method of claim 1 wherein the upper cladding is formed using a sol gel  
2 process.
- 1 15. The method of claim 13 wherein the upper cladding is bonded to the core using an  
2 adhesive.
- 1 16. The method of claim 15 wherein the adhesive comprises an epoxy.
- 1 17. The method of claim 15 wherein the adhesive has a refractive index the same as or  
2 similar to the upper cladding.
- 1 18. The method of claim 7 wherein the light propagating channel is formed in the  
2 lower cladding and at least a portion of the lower cladding is disposed below the  
3 light propagating channel.
- 1 19. The method of claim 7 wherein the light propagating channel is formed in the  
2 lower cladding and a substrate on which the lower cladding is deposited forms a  
3 lower surface of the core.
- 1 20. The method of claim 18 wherein the lower cladding disposed below the core is less  
2 than 5 $\mu$ m.
- 1 21. The method of claim 20 wherein the lower cladding disposed below the core is less  
2 than 3 $\mu$ m.

- 1 22. The method of claim 15 wherein the adhesive is selected to have a refractive index  
2 suitable to minimize loss or scattering of light conducted through the core.
- 1 23. The method of claim 18 wherein a portion of the lower cladding is disposed below  
2 the core to minimize the effects of birefringence.
- 1 24. The method of claim 6 wherein the substrate is selected to have suitable optical  
2 properties to act as a cladding and defines at least a portion of the core.
- 1 25. The method of claim 24 wherein the upper cladding is formed by disposing a panel  
2 over the substrate and the core material.
- 1 26. The method of claim 25 where in the panel is selected from the group consisting of  
2 quartz, silica, and fused silica.
- 1 27. The method of claim 1 wherein the core is formed in the lower cladding and the  
2 upper cladding is formed adjacent the upper side of the core.
- 1 28. The method of claim 1 wherein the lower cladding, the core and the upper cladding  
2 are formed by one or more processing techniques selected from the group of  
3 chemical vapor deposition, physical vapor deposition, or sol gel processing.
- 1 29. The method of claim 1 wherein the core material has a refractive index higher than  
2 the refractive index of the lower and upper claddings.
- 1 30. A method of forming waveguide structures, comprising:  
2 depositing a lower cladding on a substrate;  
3 forming a light propagating channel in the lower cladding;  
4 depositing a core material in the light propagating channel; and  
5 bonding an upper cladding to the upper surface of the lower cladding and the core.
- 1 31. The method of claim 30 wherein the lower cladding comprises a material selected  
2 from the group of USG or undoped silica.

- 1 32. The method of claim 31 wherein the panel comprises a material selected from  
2 quartz, silica, or fused silica.
- 1 33. The method of claim 31 wherein the upper cladding comprises a material having  
2 optical properties which are suitable for use as a cladding disposed adjacent the  
3 core.
- 1 34. The method of claim 30 wherein the upper cladding is bonded to the upper surface  
2 of the lower cladding and the upper surface of the core using an adhesive having a  
3 refractive index the same as or similar to the upper cladding.
- 1 35. The method of claim 30 wherein the light propagating channel is formed by  
2 patterning and etching the lower cladding using dry etch techniques.
- 1 36. The method of claim 35 wherein the core material is deposited using chemical  
2 vapor deposition techniques.
- 1 37. The method of claim 30 wherein the lower cladding is deposited to a thickness  
2 greater than the height of the light propagating channel.
- 1 38. The method of claim 30 wherein the lower cladding is deposited to a thickness  
2 equal to the height of the light propagating channel.
- 1 39. The method of claim 37 wherein the lower cladding is deposited to a thickness  
2 greater than or equal to 8 $\mu$ m.
- 1 40. The method of claim 38 wherein the lower cladding is deposited to a thickness  
2 equal to or less than 8 $\mu$ m.
- 1 41. The method of claim 30 wherein bonding an upper cladding comprises flowing a  
2 precursor fluid over the core and curing the precursor fluid.
- 1 42. A method of forming an optical device, comprising:  
2 depositing a lower cladding on a substrate;

3 depositing a core material on the lower cladding;  
4 patterning and etching the core material to define one or more core structures;  
5 forming an upper cladding on the core using a sol gel process.

1 43. The method of claim 42 wherein the upper cladding is formed by flowing a  
2 precursor solution over the core structures and then curing the precursor.

1 44. A method of forming an integrated optical device, comprising:  
2 forming one or more optical waveguide components on a substrate having an area  
3 greater than about 400 cm<sup>2</sup>.

1 45. The method of claim 44 further comprising affixing one or more active and/or  
2 passive optical components on the substrate.

1 46. The method of claim 44 wherein the optical waveguide components are selected  
2 from the group of splitters, filters, couplers, arrayed waveguide gratings,  
3 attenuators, multiplexers, de-multiplexers and combinations thereof.

1 47. The method of claim 46 further comprising one or more input/output connections.

1 48. The method of claim 47 wherein the input/output connections provide a transition  
2 between an optical fiber and a waveguide component.

1 49. The method of claim 48 wherein the input/output connections provide a transition  
2 from about 8 microns to about 5 microns or less.

1 50. The method of claim 46 wherein the substrate comprises silica, quartz, fused silica  
2 or other material having suitable optical properties to be used as a cladding in an  
3 optical waveguide component.

1 51. The method of claim 42 wherein the substrate comprises silica, quartz, fused silica  
2 or other material having suitable optical properties to enable a lower cladding  
3 having a thickness less than an upper cladding to confine a core.

- 1 52. The method of claim 44 wherein the one or more passive devices formed on the  
2 substrate are formed by depositing a lower cladding, depositing a core on the lower  
3 cladding and then forming an upper cladding on the core.
- 1 53. The method of claim 44 wherein the upper cladding is formed by depositing a film  
2 over the lower cladding and the core formed in the lower cladding or bonding a  
3 panel on the upper surface of the lower cladding and a core formed in the lower  
4 cladding.
- 1 54. The method of claim 52 wherein the core is formed by depositing a blanket layer  
2 of core material on the lower cladding, patterning the core material and etching the  
3 core material to define the core light propagating channels.
- 1 55. The method of claim 53 wherein the core is formed by etching core light  
2 propagating channels into the lower cladding and then filling the core light  
3 propagating channels with core material.
- 1 56. The method of claim 44 wherein the percent utilization of the substrate to form the  
2 one or more optical waveguide components is greater than about 70%.
- 1 57. The method of claim 53 further comprising a planarizing step performed prior to  
2 forming the upper cladding.
- 1 58. A method for forming an optical device on a substrate, comprising:  
2 forming a lower cladding on a substrate;  
3 depositing a core material on the lower cladding;  
4 patterning and etching the core material to form one or more optical devices;  
5 depositing an upper cladding on the lower cladding and the optical devices by  
6 depositing at least a portion of upper cladding and heat treating the deposited  
7 portion in situ.
- 1 59. The method of claim 58 further comprising repeating the depositing and treating  
2 steps for at least two cycles.

- 1 60. The method of claim 58 wherein the step of depositing the upper cladding layer  
2 comprises depositing a doped material.
- 1 61. The method of claim 59 wherein the doped material is BPSG.
- 1 62. The method of claim 58 wherein the doped material has a refractive index lower  
2 than the refractive index of the core material.
- 1 63. The method of claim 58 wherein the doped film is selected to have a lower flow  
2 temperature than the core material.
- 1 64. The method of claim 58 wherein heat treating comprises a rapid thermal process.
- 1 65. The method of claim 64 wherein the rapid thermal process is a single substrate  
2 process.
- 1 66. The method of claim 61 wherein the rapid thermal anneal process is sufficient to  
2 flow the doped material.
- 1 67. The method of claim 61 wherein the rapid thermal anneal process is performed at a  
2 temperature of at least about 1000°C.
- 1 68. The method of claim 63 wherein the rapid thermal anneal is conducted for less  
2 than about 70 seconds.
- 1 69. The method of claim 58 wherein the core material is PSG, GeO<sub>2</sub>, SiON, Si<sub>3</sub>N<sub>4</sub>, and  
2 silicon.
- 1 70. The method of claim 58 further comprising densifying the core.
- 1 71. A method of fabricating multiple optical devices on a substrate, comprising:  
2 positioning a substrate in a first processing chamber;  
3 depositing a lower cladding on the glass panel;  
4 densifying the deposited lower cladding;

5 positioning the glass panel in a second processing chamber;  
6 depositing a core layer on the lower cladding;  
7 patterning and etching the core layer to define a pattern of optical devices;  
8 positioning the glass panel in a third processing chamber; and  
9 depositing an upper cladding over the patterned optical devices.

1 72. The method of claim 71 wherein the upper cladding is densified following  
2 deposition thereof.

1 73. The method of claim 71 wherein the rectangular panel defines one or more die and  
2 the die have one or more optical devices formed thereon and further have a major  
3 dimension greater than a minor dimension.

1 74. The method of claim 71 wherein the utilization of the glass panel is greater than  
2 about 75%.

1 75. The method of claim 72 wherein the devices formed on a single die cover an area  
2 of at least about 400 cm<sup>2</sup>.

1 76. The method of claim 73 wherein a single die comprising one or more optical  
2 devices has a shape similar to the glass panel.

1 77. The method of claim 73 wherein the deposition steps are performed in one or more  
2 processing systems wherein each deposition step requiring densification is  
3 performed on a system having at least one deposition chamber and at least one  
4 densification chamber.

1 78. The method of claim 73 wherein the die and the substrate have the same form  
2 factor.

1 79. The method of claim 73 wherein the at least two sides of a die are parallel to at  
2 least two sides of the glass panel on which the die are formed.

1 80. The method of claim 71 wherein the rectangular panel is 400mm by 500mm.



- 1 81. The method of claim 71 wherein the rectangular panel has an area of about 400cm<sup>2</sup>  
2 or greater.
- 1 82. The method of claim 71 wherein the rectangular panel is a TFT panel.
- 1 83. The method of claim 71 wherein the rectangular panel is made of a material  
2 selected from the group of quartz, silica, fused silica or combinations thereof.
- 1 84. The method of claim 71 wherein the lower cladding is made of a material selected  
2 from the group of USG, undoped silica, or combinations thereof.
- 1 85. The method of claim 84 wherein the core is made of a material selected from the  
2 group of PSG, GeO<sub>2</sub>, SiON, Si<sub>3</sub>N<sub>4</sub>, and silicon.
- 1 86. The method of claim 85 wherein the upper cladding is made of a material selected  
2 from the group of BPSG.
- 1 87. The method of claim 71 wherein the step of depositing a lower cladding layer and  
2 densifying the lower cladding is performed on the same processing system.
- 1 88. The method of claim 71 wherein depositing the core material is performed by a  
2 damascene process.
- 1 89. A processing system for fabricating optical devices, comprising:  
2 a transfer chamber having a robot disposed therein;  
3 one or more deposition chambers connected to the transfer chamber, the deposition  
4 chambers selected from the group of a USG chamber, a PSG chamber, and a BPSG  
5 chamber; and  
6 at least one densification chamber connected to the transfer chamber.
- 1 90. The processing system of claim 89 wherein the deposition chambers comprise  
2 thermal CVD chambers, PECVD chambers, mixed frequency PECVD chambers  
3 and PVD chambers.

- 1 91. The processing system of claim 90 wherein the at least one densification chamber  
2 comprises a rapid thermal anneal chamber.
- 1 92. The processing chamber of claim 91 wherein the PECVD chambers are parallel  
2 plate type chambers.
- 1 93. The processing system of claim 91 wherein the at least one rapid thermal anneal  
2 chamber comprises a lamp type thermal processing chamber.
- 1 94. The processing system of claim 89 comprising at least one USG deposition  
2 chamber, at least one PSG deposition chamber and at least one densification  
3 chamber.
- 1 95. The processing system of claim 89 comprising at least one BPSG deposition  
2 chamber and at least one densification chamber.
- 1 96. The processing system of claim 94 wherein the processing system is adapted to  
2 process substrates having an area of at least about 400cm<sup>2</sup>.
- 1 97. The processing system of claim 94 wherein the processing system is adapted to  
2 process substrates having an area of at least about 400cm<sup>2</sup>.
- 1 98. A method for forming a portion of an optical device on a flat panel, comprising:  
2 positioning a flat panel in a first processing chamber on a processing system;  
3 depositing a lower cladding layer on the substrate;  
4 positioning the substrate in a densification chamber on the same processing system  
5 and treating the substrate therein;  
6 positioning the substrate in second deposition chamber to deposit a core layer on  
7 the lower cladding layer; and  
8 positioning the substrate in the densification chamber on the processing system and  
9 treating the substrate therein.
- 1 99. The method of claim 98 wherein the lower cladding layer comprises USG and the  
2 core layer comprises PSG.

- 1 100. The method of claim 99 wherein treating the substrate in the densification chamber  
2 comprises exposing the substrate to a rapid thermal anneal process.
- 1 101. The method of claim 100 wherein the substrate is heated to a temperature above  
2 about 1000°C.
- 1 102. The method of claim 100 further comprising performing lithography steps on the  
2 substrate to define a core pattern and then depositing an upper cladding on the core  
3 pattern and then treating the substrate in a densification chamber.
- 1 103. The method of claim 102 wherein the flat panel has an area of at least about  
2 400cm<sup>2</sup>.
- 1 104. The method of claim 103 wherein the flat panel has a major side longer than a  
2 minor side.
- 1 105. The method of claim 103 wherein the flat panel is made of a material selected from  
2 the group of quartz, silica, and fused silica.
- 1 106. A method of forming an optical device on a substrate, comprising depositing one  
2 or more of a lower cladding, a core and an upper cladding and heat treating one or  
3 more of the lower cladding, the core and the upper cladding in situ following  
4 deposition thereof.
- 1 107. The method of claim 106 further comprising depositing the core layer and forming  
2 one or more light propagating channels in the core.
- 1 108. The method of claim 107 wherein the upper cladding is heat treated in situ  
2 following deposition thereof.
- 1 109. The method of claim 108 wherein the lower cladding is heat treated in situ  
2 following deposition thereof.

- 1 110. The method of claim 106 wherein the lower cladding is heat treated in situ  
2 following deposition thereof.
- 1 111. The method of claim 110 wherein the upper cladding is heat treated in situ  
2 following deposition thereof.
- 1 112. The method of claim 106 wherein the core is heat treated in situ following  
2 deposition thereof.
- 1 113. The method of claim 108 further comprising depositing an encapsulation layer  
2 over the upper cladding.